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Trapeziometacarpal subluxation predisposes to incident trapeziometacarpal osteoarthritis (OA): the Framingham Study[1]

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Summary

Objective: Osteoarthritis (OA) of the thumb carpo-metacarpal joint is a common condition that can lead to substantial pain, instability, deformity, and loss of motion. It has been hypothesized that instability of the trapeziometacarpal joint combined with strenuous use can potentially lead to OA. However, as yet there have been no longitudinal evaluations to determine if this hypothesis is true. We examined the relation of radial subluxation to the risk of radiographic OA at trapeziometacarpal joint.

Methods: We conducted a nested case–control study. We restricted our evaluation of cases to subjects with no radiographic trapeziometacarpal OA at baseline (1967). We defined incident trapeziometacarpal OA as the development of a modified Kellgren and Lawrence grade $\geq$ 2 in that joint at a later examination (1992–1993). Radial subluxation of the base of the first metacarpal off the trapezium and the amount of the base of the first metacarpal covering the articulating surface of the trapezium were measured using a digital calculation caliper. We examined the relation of gender-specific quartile groups of radial subluxation to the risk of trapeziometacarpal OA using a conditional logistic regression model.

Results: We assessed 203 men and 431 women. After adjusting for age, handedness, number of other joints with OA, and grip strength, the odds ratios for the risk of trapeziometacarpal OA in men were 1.0, 1.8, 2.7, and 3.1 from the lowest quartile of radial subluxation to the highest quartile, respectively (P for trend = 0.015). There was no significant relationship between radial subluxation quartiles and incident trapeziometacarpal OA in women.

Conclusion: This study provides evidence that radial subluxation predisposes to subsequent OA of the trapeziometacarpal joint in men.

Key words: Trapeziometacarpal subluxation, Trapeziometacarpal osteoarthritis.

Introduction

Little is known about risk factors that contribute to hand osteoarthritis (OA). Identifying risk factors for base of thumb OA will be important given the high prevalence and impact of disease in this joint[1]. OA of the thumb carpo-metacarpal (CMC) joint is a common condition that can lead to substantial pain, instability, deformity, and loss of motion[2]. Over the age of 70 years, approximately 5% of women and 3% of men have symptomatic OA affecting this joint with impairment of hand function[1].

The agility of the thumb is afforded mainly by the mobility of the trapeziometacarpal joint or so-called base of thumb joint[3–5]. The trapeziometacarpal joint is a biconcave and anatomically incongruent saddle joint that facilitates the wide circumduction motion of the thumb, which is important for activities involving grasp and pinch. Inherent to this wide range of mobility is its instability. Relative stability of this joint is afforded by surrounding muscles, capsule, and constraining ligaments. Despite these support structures, the joint often lies in anatomically incongruous positions. Also, the base of thumb absorbs a high degree of compressive and shear stresses during pinch, grasp and direct compression. It has been theorized that as a result of a combination of these factors, the joint is highly susceptible to OA.

A number of different mechanisms of trapeziometacarpal instability have been proposed that may predispose to OA in this joint[6]: including, ligamentous laxity due to hormonal change[3], hypoplasia of the trapezial joint surface[7], and abnormality of the abductor pollicis longus[8]. Eaton and Littler[3] proposed that together these abnormalities would predispose to instability of the trapeziometacarpal joint and combined with strenuous use potentially lead to OA. However, as yet there have been no longitudinal evaluations to determine if these hypotheses are true.

We examined the relation of radial subluxation, an indicator of laxity of the thumb base, to the risk of incident radiographic OA at trapeziometacarpal joint among participants in the Framingham Osteoarthritis Study.

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Materials and methods

The Framingham Study was established in 1948 in the town of Framingham, Massachusetts. Subjects have been examined biennially since then. The original cohort included 5209 subjects who were 26–62 years of age at the first examination. All subjects in the current study are Caucasians. In 1967–1969, as part of an osteoporosis study conducted during biennial examinations 10 and 11, a baseline radiograph of the right hand was obtained. A follow-up radiograph of both hands was obtained in 1992–1993 (biennial examination 22), roughly 24 years later, as part of an OA study.

At each examination, participants received a medical history interview and a physical examination. Maximal grip strength (kilograms) was assessed using an adjustable, hand-held dynamometer and standardized positioning as previously described[9].

HAND RADIOGRAPHS

Posteroanterior hand radiographs were taken with separate exposures for each hand with the central ray on the third metacarpophalangeal joint. Each radiograph was read by one of two academically based bone and joint radiologists using an atlas of individual radiographic features developed for the Framingham Osteoarthritis Study[10]. Fifteen joints for each hand, including five distal interphalangeal (DIP), four proximal interphalangeal (PIP), five metacarpophalangeal (MCP), and base of thumb joints were evaluated for the presence of osteophytes, joint space narrowing, sclerosis, and cysts. Each joint was graded for overall radiographic OA using a modified Kellgren and Lawrence (K/L) scale graded 0–4, where 0 = none, 1 = questionable osteophyte(s) and/or questionable joint space narrowing, 2 = definite small osteophyte(s) and/or mild joint space narrowing, 3 = definite moderate osteophyte(s) and/or moderate joint space narrowing, and 4 = large osteophyte(s) and/or severe joint space narrowing (cysts or sclerosis may be present)[10]. This modification allowed for a joint to be scored as having definite OA (grade 2 or higher) based on the presence of joint space narrowing alone, in the absence of osteophytes. The intra-observer reliability (kappa statistic) was 0.79 for reader 1 and 0.82 for reader 2; the kappa statistic for interobserver reliability was 0.65 for radiographic scoring of modified K/L grade[10].

CASE–CONTROL STUDY AND DEFINITION OF VARIABLES

We conducted a case–control study within the Framingham cohort study. We restricted our evaluation of cases to subjects with no radiographic trapeziometacarpal OA at baseline (i.e., trapeziometacarpal joint with K/L score < 2 at baseline (1967 visit)), and we focused on the right hand only because the left was not evaluated by radiography at baseline. We defined incident trapeziometacarpal OA as the development of a K/L grade ≥ 2 in that joint at examination 22 (1992–1993). A case is defined as a random sample of participants who did not have radiographic trapeziometacarpal OA at baseline, and developed incident radiographic trapeziometacarpal OA at the time of follow-up (Visit 22 in 1992–1993). For each case we randomly selected up to two controls matched by age and sex from the baseline population, irrespective of OA status at follow-up.

Seven hundred and forty-six participants had baseline and follow-up radiographs. Subjects without follow-up hand radiographs or with rheumatoid arthritis were excluded. A diagnosis of rheumatoid arthritis was defined as present when subjects were either taking second line drugs for arthritis and/or their hand radiographs showed marginal erosions or other findings highly suggestive of an inflammatory arthropathy.

The 1967 right hand film was assessed for radial trapeziometacarpal subluxation by an observer blinded both to the hypothesis under investigation and to whether the subject was a case or a control. The reader measured the extent of radial subluxation of the base of the first metacarpal off the trapezium (A) and the amount of the base of the first metacarpal covering the articulating surface of the trapezium (B) using a digital calculation caliper (Digit-Cal, Browne and Sharpe) (see Fig. 1). We calculated the radial subluxation ratio, i.e., (A)/(A + B), and used it as an indicator of laxity of the thumb base. The intra-observer intra-class correlation for the ratio was 0.89. This is analogous to the method described by Eaton *et al.* for assessing laxity of the trapeziometacarpal joint with lateral shift of the metacarpal off the saddle of the trapezium in the lax joint[4,5].

STATISTICAL ANALYSIS

For each gender, we divided the ratio of radial subluxation into groups by quartiles. We examined the relation of quartile groups of radial subluxation to the risk of incident trapeziometacarpal OA using a conditional logistic regression model. In the model, we adjusted for age, body mass index (BMI), handedness, grip strength, and number of other hand joints with OA at baseline. In this analysis, the data on OA status and maximal grip strength were taken from the same hand. We assessed prevalent hand OA in other hand joints, e.g., DIP, PIP, or MCP, as having radiographic OA if K/L ≥ 2.

Results

At the baseline visit (see Table I) male cases were on average 4.0 pounds heavier, had more OA in other hand joints and had higher grip strength than controls. The female cases were on average 3 pounds heavier and had more prevalent hand OA than controls.

In men the mean subluxation ratio was significantly higher in cases (0.46, SD = 0.08) than controls (mean = 0.43, SD = 0.08) ($P = 0.03$); however no such difference was observed in female cases (mean = 0.45, SD = 0.06) and controls (mean = 0.45, SD = 0.07) ($P = 0.78$).

After adjusting for age, handedness, number of other joints with OA, and grip strength, the odds ratios for the risk of trapeziometacarpal OA in men were 1.0, 1.8, 2.7, and 3.1 from the lowest quartile of radial subluxation to the highest quartile, respectively (P for trend = 0.0150) (Table II). There was no significant relationship between radial subluxation quartiles and incident trapeziometacarpal OA in women.

Discussion

We have demonstrated that radial subluxation of the base of the first metacarpal carries a substantial risk for subsequent development of trapeziometacarpal OA in men. The relationship was found when comparing the highest quartile to the lowest in men with a significant trend for the remaining quartiles. This study did not demonstrate a similarly increased risk for women.

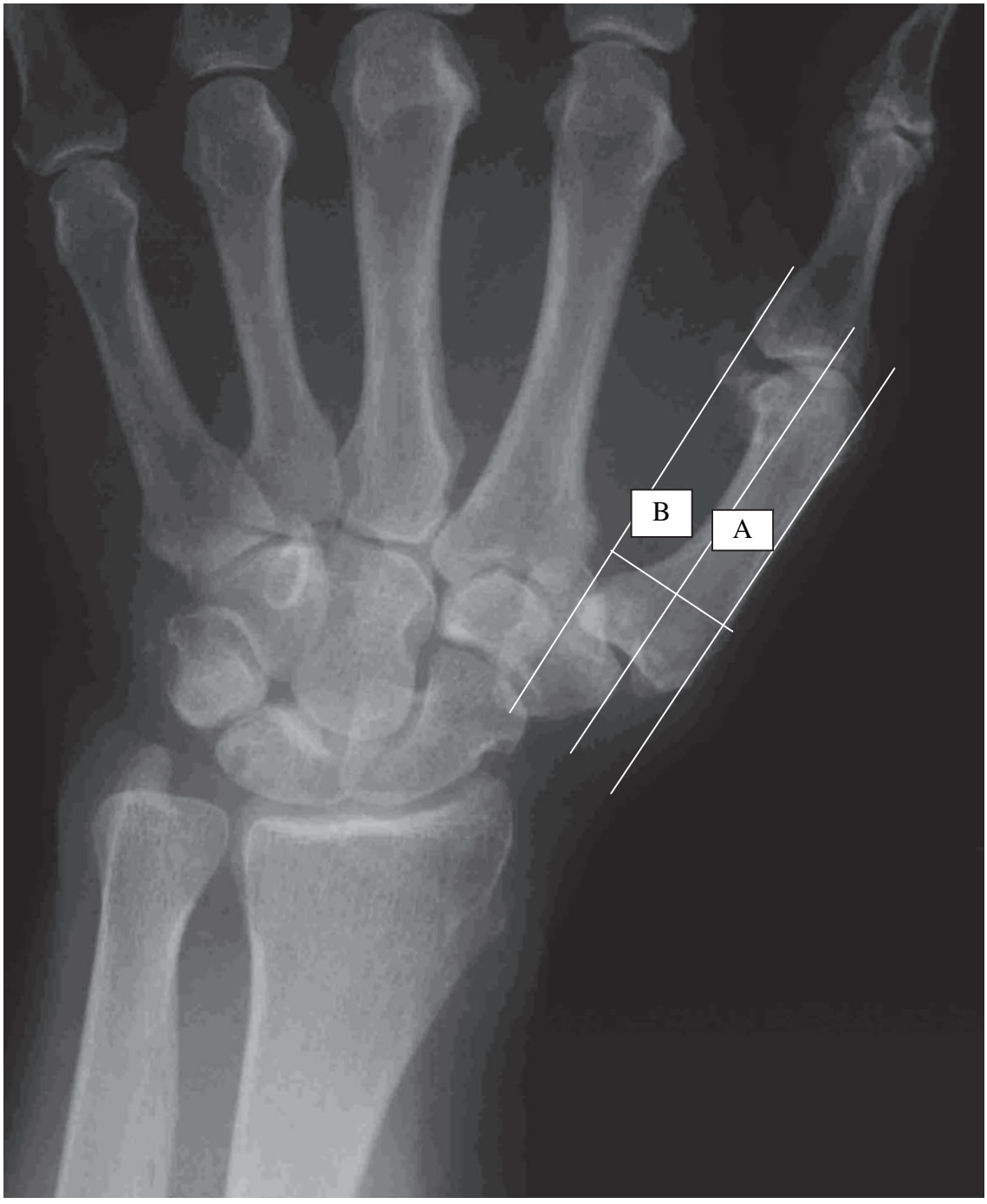

Fig. 1. Radial subluxation of base of first metacarpal. Extent of radial subluxation of the base of the first metacarpal off the trapezium (A). The amount of the base of the first metacarpal covering the articulating surface of the trapezium (B).

The basal joint complex of the thumb is integral to the functional prowess of the human hand[11]. With the evolution from the rudimentary primate thumb base to the human hand, stability at the base of the thumb was compromised in the interest of mobility and refinement of a dominant prehensile digit[12]. Indeed, the trapeziometacarpal articulation of our simian ancestors functioned as a single axis hinge, affording only flexion–extension of the thumb in the plane of the palm. In dissections of these specimens, no evidence of degenerative arthritic disease has been identified in this simplified precursor of the human thumb[11,12].

The human hand may have compromised stability in order to pinch and grasp. Joint compression (contact) forces of approximately 12 kg occur at the trapeziometacarpal joint during simple pinch (1 kg of applied force). Compression forces of as much as 120 kg may occur at the trapeziometacarpal joint during strong grasp[13]. The transmission of these high compressive forces in both pinch and grasp requires a stable trapeziometacarpal joint to resist them.

Table I
Study population characteristics at baseline

	Incident TRP* OA	Control	*P*-value
Men	($n = 72$)	($n = 131$)	
Age (mean ± SD, years)	54.1 ± 5.5	54.0 ± 5.3	0.93
Weight (mean ± SD, lb)	181.7 ± 23.7	177.7 ± 23.2	0.24
BMI (mean ± SD, lb)	27.2 ± 2.6	26.5 ± 2.9	0.14
Grip strength (kg)	50.2 ± 8.7	48.8 ± 8.7	0.28
Prevalence of OA in any of the other 14 hand joints at baseline (%)	38.0	29.2	0.03
No. of joints with OA in other 14 hand joints at baseline	1.2 (mean) 0 (median) 0–13 (range)	0.6 (mean) 0 (median) 0–7 (range)	0.04
Women	($n = 215$)	($n = 216$)	
Age (mean ± SD, years)	55.5 ± 5.9	55.4 ± 6.1	0.95
Weight (mean ± SD, lb)	143.2 ± 22.7	140.0 ± 22.3	0.14
BMI (mean ± SD, lb)	25.3 ± 3.8	25.0 ± 3.6	0.46
Grip strength (kg)	26.4 ± 4.9	25.7 ± 5.1	0.11
Prevalence of OA in any of the other 14 hand joints at baseline (%)	46.5	37.5	0.06
No. of joints with OA in other 14 hand joints at baseline	1.2 (mean) 0 (median) 0–10 (range)	0.9 (mean) 0 (median) 0–10 (range)	0.11

*TRP: Trapeziometacarpal.

These forces can predispose to ligament laxity and incompetence, and subsequently trapeziometacarpal joint subluxation and instability. Trapeziometacarpal joint instability and incongruence remain the prevailing explanations for the etiology of basal joint OA[14]. Incongruity and instability are thought to lead to areas of high contact stress within the joint, thus producing cartilage erosion and subsequent OA[14]. However, until the data presented in this study, there have been no longitudinal evaluations that have demonstrated the importance of subluxation in predisposing to trapeziometacarpal OA.

Why the marked differences between the results in men and women? In order to develop instability and subluxation, it is likely that large forces are required to be transmitted through the hand. In this study the magnitude of grip strength was approximately two times greater in men than it was in women. Similarly previous studies have demonstrated that the effect of grip strength in predisposing to thumb base OA is much greater in men than it is in women[15]. Potentially men are more exposed to manual activities involving strong grasping than women. We would hypothesize that grasping activities and high grip strength predispose to subsequent joint instability, and subluxation then predisposes the joint to OA. Previous research by Ateshian *et al.*[16,17] has suggested that women have a smaller trapezium, and that their joints are less congruent than those of men. Our study did not examine congruence but rather stability or subluxation, and the combination of both of these factors likely predisposes to OA.

There are a number of limitations of this study that need to be mentioned. The examination of radiographs was limited to those of the right hand only. Given that this is the dominant hand in most people, and that this is the hand most likely to be used for heavy activities, this may well represent an overestimation of the magnitude of the effect for the left hand.

The radiographic view obtained was not a stress view of the trapeziometacarpal joint as described by Eaton and Littler[3]. As such, the ratio of radial subluxation is likely less than would be obtained by a stress view. As a result the technique that we have used may well underestimate the size of the effect.

This analysis may also be susceptible to survivor bias as between the 1967 visit and 1992 a number of the elderly subjects in the Framingham cohort died. However, in order for this survivor bias to affect the validity of our study, subjects with small trapezii who were not at increased risk of CMC OA and who were men, would have had to die more often than other men, which seems unlikely. When we examined this formally the subjects who died before follow-up were more likely to be men, had older age, higher BMI, more hand joints with ROA among the other 14 joints at baseline compared to those who had follow-up hand films.

A further limitation of this research is that we did not adjust for occupation. Our exploratory analyses did not detect any influence of this variable, and previous analyses in this predominantly "white collar" population have found no difference after adjusting for occupation[1,9,10,15].

This study provides evidence that radial subluxation predisposes to subsequent OA of the trapeziometacarpal joint in men. It may be possible that an intervention such as splinting or occupational advice in subjects who have detectable subluxation could reduce this risk, and this warrants further investigation. Further research of the amount of subluxation using stress views may enhance the ability to reliably detect meaningful subluxation but again this merits further investigation. Similarly the role of subluxation in disease progression also merits further attention.

Table II
*Odds ratio (95% CI) of sex-specific quartiles of subluxation ratio for incident trapeziometacarpal OA**

Adjusting	Low (Ref.)	Second	Third	Highest quartile	*P* for trend
Men					
Subluxation ratio range	0.27–0.40	0.40–0.46	0.47–0.50	0.51–0.67	
No. of cases	18	18	18	18	
No. of controls	48	36	25	22	
Multivariable adjusted model†	1.0	1.8 (0.7,4.4)	2.7 (1.0, 6.9)	3.1 (1.2, 8.2)	0.0150
Women					
Subluxation ratio range	0.21–0.40	0.41–0.45	0.46–0.49	0.50–0.62	
No. of cases	53	54	54	54	
No. of controls	64	45	46	61	
Multivariable adjusted model†	1.0	1.5 (0.8, 2.7)	1.5 (0.9, 2.8)	1.1 (0.6, 2.1)	0.4806

*A/A + B is shown in Fig. 1.
†Model adjusted for age, BMI, handedness, *N* of joints with OA in other 14 hand joints, and grip strength (quartile).

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